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REMOTE COMMUNICATION DEVICES, RADIO FREQUENCY IDENTIFICATION DEVICES, WIRELESS COMMUNICATION SYSTEMS, WIRELESS COMMUNICATION METHODS, RADIO FREQUENCY IDENTIFICATION DEVICE COMMUNICATION METHODS, AND METHODS OF FORMING A REMOTE COMMUNICATION DEVICE

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REMOTE COMMUNICATION DEVICES, RADIO FREQUENCY IDENTIFICATION DEVICES, WIRELESS COMMUNICATION SYSTEMS, WIRELESS COMMUNICATION METHODS, RADIO FREQUENCY IDENTIFICATION DEVICE COMMUNICATION METHODS, AND METHODS OF FORMING A REMOTE COMMUNICATION DEVICE

TECHNICAL FIELD

The present invention relates to remote communication devices, radio frequency identification devices, wireless communication systems, wireless communication methods, radio frequency identification device communication methods, and methods of forming a remote communication device.

BACKGROUND OF THE INVENTION

Electronic identification systems typically comprise two devices which are configured to communicate with one another. Preferred configurations of the electronic identification systems are operable to provide such communications via a wireless medium.

One such configuration is described in U.S. Patent Application Serial Number 08/705,043, filed August 29, 1996, assigned to the assignee of the present application, and incorporated herein by reference. This application discloses the use of a radio frequency (RF) communication system including communication devices. The disclosed communication devices include an interrogator and a remote transponder, such as a tag or card.

Such communication systems can be used in various applications such as identification applications. The interrogator is configured to output a polling or interrogation signal which may comprise a radio frequency signal including a predefined code. The remote transponders of such a communication system are operable to transmit an identification signal responsive to receiving an appropriate polling or interrogation signal.

More specifically, the appropriate transponders are configured to recognize the predefined code. The transponders receiving the code can subsequently output a particular identification signal which is associated with the transmitting transponder. Following transmission of the polling signal, the interrogator is configured to receive the identification signals enabling detection of the presence of corresponding transponders.

Such communication systems are useable in identification applications such as inventory or other object monitoring. For example, a remote identification device is initially attached to an object of interest. Responsive to receiving the appropriate polling signal, the identification device is equipped to output an identification signal. Generating the identification signal identifies the presence or location of the identification device and the article or object attached thereto.

Some conventional electronic identification systems utilize backscatter communication techniques. More specifically, the interrogator outputs a polling signal followed by a continuous wave (CW) signal. The remote communication devices are configured to modulate the

continuous wave signal in backscatter communication configurations. This modulation typically includes selective reflection of the continuous wave signal. The reflected continuous wave signal includes the reply message from the remote devices which is demodulated by the interrogator.

SUMMARY OF THE INVENTION

The present invention relates to remote communication devices, radio frequency identification devices, wireless communication systems, wireless communication methods, radio frequency identification device communication methods, and methods of forming a remote communication device.

According to one aspect of the invention, a wireless communication system is provided. The wireless communication system comprises an interrogator and one or more remote communication devices individually configured to communicate with the interrogator in at least one embodiment. Exemplary remote communication devices include remote intelligent communication devices or radio frequency identification devices (RFID).

One configuration of the remote communication device includes communication circuitry and at least one antenna configured to communicate at a plurality of frequencies. The antenna is substantially tuned to plural frequencies to implement communications. The remote communication device includes a transmit antenna and receive antenna in one embodiment. An exemplary transmit antenna comprises a dipole

antenna and an exemplary receive antenna comprises a loop antenna. The remote communication device is configured for backscatter communications in at least one arrangement.

The invention additionally provides methods and additional structural aspects as described below.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the invention are described below with reference to the following accompanying drawings.

Fig. 1 is a functional block diagram of an exemplary communication system.

Fig. 2 is a front view of a wireless remote communication device according to one embodiment of the invention.

Fig. 3 is a front view of an employee badge according to another embodiment of the invention.

Fig. 4 is an illustrative representation of one substrate surface of a remote communication device.

Fig. 5 is an illustrative representation of exemplary dimensions of a transmit antenna of the remote communication device.

Fig. 6 is an illustrative representation of additional exemplary dimensions of the transmit antenna.

Fig. 7 is an illustrative representation of exemplary dimensions of a receive antenna of the remote communication device.

Fig. 8 is an illustrative representation of an exemplary conductive trace formed upon another substrate surface of the remote communication device.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

This disclosure of the invention is submitted in furtherance of the constitutional purposes of the U.S. Patent Laws "to promote the progress of science and useful arts" (Article 1, Section 8).

Fig. 1 illustrates a wireless communication system 10 embodying the invention. Communication system 10 is configured as an electronic identification system in the embodiment described herein. Other applications of communication system 10 are possible. Further, the described communication system 10 is configured for backscatter communications as described further below. Other communication protocols are utilized in other embodiments.

The depicted communication system 10 includes at least one electronic wireless remote communication device 12 and an interrogator 26. Radio frequency communications can occur intermediate remote communication device 12 and interrogator 26 for use in identification systems and product monitoring systems as exemplary applications.

Devices 12 include radio frequency identification devices (RFID) or remote intelligent communication (RIC) devices in the exemplary embodiments described herein. Remote intelligent communication devices

can perform functions in addition to identification functions. Exemplary devices 12 are disclosed in U.S. Patent Application Serial No. 08/705,043, filed August 29, 1996. Plural wireless remote communication devices 12 typically communicate with interrogator 26 although only one such device 12 is illustrated in Fig. 1. Such a remote communication device 12 can be referred to as a tag or card as illustrated and described below.

Although multiple remote communication devices 12 can be employed in communication system 10, there is typically no communication between multiple devices 12. Instead, the multiple communication devices 12 communicate with interrogator 26. Multiple communication devices 12 can be used in the same field of interrogator 26 (i.e., within the communications range of interrogator 26). Similarly, multiple interrogators 26 can be in proximity to one or more of remote communication devices 12.

The above described system 10 is advantageous over prior art devices that utilize magnetic field effect systems because, with system 10, a greater range can be achieved, and more information can be communicated (instead of just identification information). As a result, such a system 10 can be used, for example, to monitor large warehouse inventories having many unique products needing individual discrimination to determine the presence of particular items within a large lot of tagged products.

Remote communication device 12 is configured to interface with interrogator 26 using a wireless medium in one embodiment. More specifically, communications intermediate communication device 12 and interrogator 26 occur via an electromagnetic link, such as an RF link (e.g., at microwave frequencies) in the described embodiment. Interrogator 26 is configured to output forward link wireless communications 27. Further, interrogator 26 is operable to receive reply or return link wireless communications 29 from remote communication devices 12 responsive to the outputting of forward link communication 27.

In accordance with the above, forward link communications 27 and return link communications 29 individually comprise wireless signals, such as radio frequency signals, in the described embodiment. Other forms of electromagnetic communication, such as infrared, etc., are possible.

Interrogator unit 26 includes a plurality of antennas X1, R1, as well as transmitting and receiving circuitry, similar to that implemented in devices 12. Antenna X1 comprises a transmit antenna and antenna R1 comprises a receive antenna individually connected to interrogator 26.

In operation, interrogator 26 transmits the interrogation command or forward link communication signal 27 via antenna X1. Communication device 12 is operable to receive the incoming forward link signal. Upon receiving signal 27, communication device 12 is

operable to respond by communicating the responsive reply or return link communication signal 29.

In one embodiment, responsive signal 29 is encoded with information that uniquely identifies, or labels the particular device 12 that is transmitting, so as to identify any object, animal, automobile, person, etc., with which remote communication device 12 is associated.

More specifically, remote communication device 12 is configured to output an identification signal within reply link communication 29 responsive to receiving forward link wireless communication 27. Interrogator 26 is configured to receive and recognize the identification signal within the return or reply link communication 29. The identification signal can be utilized to identify the particular transmitting communication device 12.

Referring to Fig. 2, one embodiment of remote communication device 12 is illustrated. The depicted remote communication device 12 includes communication circuitry 16 having a receiver and a transmitter. Communication circuitry 16 may be implemented as transponder circuitry in one configuration. Exemplary communication circuitry 16 includes a small outline integrated circuit (SOIC) 19 available as radio frequency identification device (RFID) circuitry from Micron Communications Inc., 3176 South Denver Way, Boise, Idaho 83705 under the trademark MicroStamp (TM) Engine and having designations MSEM256X10SG, MT59RC256R1FG-5.

Communication circuitry 16 is configured to receive and process communication signals. Exemplary processing includes analyzing the received communication signal for identification information and processing commands within the communication signal. More or less processing can be performed by communication circuitry 16. Thereafter, communication circuitry 16 selectively generates communication signals for communication to interrogator 26. Remote communication device 12 further includes a power source 18 connected to communication circuitry 16 to supply operational power to communication circuitry 16 including integrated circuit 19.

Power source 18 is a thin film battery in the illustrated embodiment, however, in alternative embodiments, other forms of power sources can be employed. If the power source 18 is a battery, the battery can take any suitable form. Preferably, the battery type will be selected depending on weight, size, and life requirements for a particular application. In one embodiment, battery 18 is a thin profile button-type cell forming a small, thin energy cell more commonly utilized in watches and small electronic devices requiring a thin profile. A conventional button-type cell has a pair of electrodes, an anode formed by one face and a cathode formed by an opposite face. In an alternative embodiment, the battery comprises a series connected pair of button type cells.

Communication device 12 further includes at least one antenna connected to communication circuitry 16 and configured for at least one

of wireless transmission and reception. In the illustrated embodiment, communication device 12 includes at least one receive antenna 44 connected to communication circuitry 16 for radio frequency reception by communication circuitry 16, and at least one transmit antenna 46 connected to communication circuitry 16 for radio frequency transmission by communication circuitry 16.

Receive antenna 44 is configured to receive forward wireless signals 27 and apply communication signals corresponding to the received wireless signals to communication circuitry 16. Transmit antenna 46 is configured to receive generated communication signals from communication circuitry 16 and output remote wireless signals 29 corresponding to the generated communication signals. The described antennas are implemented as printed microstrip antennas in one configuration. Further, receive antenna 44 comprises a loop antenna and the transmit antenna 46 comprises a dipole antenna in the described configuration. Transmit antenna 46 has plural dipole halves 47, 48 in the configuration illustrated in Fig. 4.

Communication device 12 can be included in any appropriate housing or packaging. Fig. 2 shows but one example of a housing in the form of a miniature housing 11 encasing device 12 to define a tag which can be supported by an object (e.g., hung from an object, affixed to an object, etc.).

Referring to Fig. 3, an alternative configuration of remote communication device 12a is illustrated. Fig. 3 shows remote

communication device 12a having a housing 11a in the form of a card. Card housing 11a preferably comprises plastic or other suitable material. Remote communication device 12a may be utilized as an employee identification badge including the communication circuitry 16. In one embodiment, the front face of housing 11a has visual identification features such as an employee photograph or a fingerprint in addition to identifying text.

Although two particular types of housings have been disclosed, the communication device 12 can be included in any appropriate housing. Communication device 12 is preferably of a small size that lends itself to applications employing small housings, such as cards, miniature tags, etc. Larger housings can also be employed. The communication device 12, provided in any appropriate housing, can be supported from or attached to an object in any desired manner.

Referring to Fig. 4, further details of one configuration of remote communication device 12 are shown. The illustrated remote communication device 12 includes a substrate 50 having plural surfaces (surface 52 is shown in Fig. 4). The illustrated substrate 50 has exemplary dimensions including a length l of 60 mm and a width w of 53 mm.

In the described configuration of remote communication device 12, substrate 50 comprises FR4 board. Conductive traces 53 are provided upon surface 52 of substrate 50 to form desired circuitry including

interconnections, antennas, etc. Such traces 53 can be formed by etching copper cladding provided upon surface 52.

As shown, conductive traces 53 include receive antenna 44 and transmit antenna 46 individually formed upon surface 52. In addition, traces 53 include power source connections for coupling with power source 18 (shown in phantom in Fig. 3). More specifically, power source connections include a positive voltage connection 54 and a negative voltage connection 56 as shown.

A negative terminal of power source 18 may be electrically coupled directly with negative connection 56. In the described configuration, power source 18 is seated upon and coupled directly above negative connection 56.

An elevated support connection 58 is formed elevationally above power source 18 and substrate surface 52. Elevated support connection 58 is coupled with a positive terminal of power source 18. The positive terminal can be opposite the negative terminal of power source 18 which is coupled with negative connector 56. Plural conductive posts 60 are provided to couple elevated support connection 58 with positive connection 54.

A via connection 62 is shown formed through substrate 50. Via connection 62 provides coupling of negative connection 56 formed upon surface 52 to an opposing surface of substrate 50 shown in Fig. 8. Via connection 62 can provide coupling to a ground plane formed upon the opposing surface as described below in further detail. Positive

connection 54 couples conductive posts 60 with receive antenna 44 and a pin 3 (positive voltage input) of integrated circuit 19. Antenna 44 is additionally coupled with a pin 7 (RX input) of integrated circuit 19 as shown.

Conductive traces 53 formed upon surface 52 also couple communication circuitry 16 and a capacitor 64 with other circuitry as illustrated. Capacitor 64 is coupled with one lead of receive antenna 44 and a via connection 66. Via connection 66 provides electrical coupling of capacitor 64 with a ground connection upon the opposing surface of substrate 50. Accordingly, capacitor 64 operates to provide coupling of positive connection 54 with the ground reference voltage of power source 18. Capacitor 64 is a 0.1 microfarad capacitor in the described embodiment sufficient to provide static discharge protection.

The formed conductive traces 53 also operate to couple the lead of receive antenna 44 with pin 7 of integrated circuit 19. Pins 5, 6 of integrated circuit 19 are coupled with respective via connections 68, 69. Via connections 68, 69 provide electrical connection through substrate 50 to a transmission line described with reference to Fig. 8. Via connections 71, 73 are coupled with opposite ends of the transmission line and dipole halves 47, 48 of transmit antenna 46. Integrated circuit 19 is electrically coupled with a plurality of pin connections 67 of conductive traces 53. Plural pins 9, 13-16 of integrated circuit 19 are coupled with a via connection 74 which is

coupled through the ground plane to the negative terminal of power source 18.

In the illustrated configuration including power source 18 within receive antenna 44, receive antenna 44 is tuned to a first frequency (approximately 915 MHz in the described embodiment). Power source 18 provides capacitive loading which assists with tuning of antenna 44 to the desired frequency.

Receive antenna 44 further includes an impedance reduction strip 70 provided in a substantially rectangular configuration in the depicted embodiment. Other configurations of impedance reduction strip 70 are possible. Impedance reduction strip 70 comprises a conductor which operates to effectively lower the impedance of receive antenna 44 and provide enhanced operation of antenna 44 at another higher frequency (e.g., 2.45 GHz) without excessive degradation of communication at the first frequency (e.g., 915 MHz).

Thus, with impedance reduction strip 70, receive antenna 44 is substantially tuned to a plurality of independent frequency bands individually having a bandwidth of approximately twenty percent of the highest center frequency (e.g., +/- 200 MHz for 2.45 GHz). Receive antenna 44 is tuned to plural exclusive non-overlapping frequency bands in the described arrangement. Receive antenna 44 is configured to communicate wireless signals at a plurality of substantially resonant frequencies. More specifically, the illustrated configuration of receive

antenna 44 can electromagnetically communicate with a return loss of less than or equal to approximately -9 dB at the plural frequencies.

The illustrated configuration of transit antenna 46 includes plural vertical portions and horizontal portions. More specifically, dipole half 47 includes a vertical portion 80 and a horizontal portion 82. Dipole half 48 includes a vertical portion 84 and a horizontal portion 86.

Additionally, transmit antenna 46 includes an impedance reduction strip 72 formed in one exemplary configuration as illustrated in Fig. 4. Impedance reduction strip 72 is a conductor formed adjacent one of the leads of transmit antenna 46. Impedance reduction strip 72 operates to reduce the impedance of dipole half 48 of transmit antenna 46 in the depicted configuration. Other arrangements for impedance reduction strip 72 are possible.

The illustrated transmit antenna 46 is configured to communicate wireless signals at a plurality of substantially resonant frequencies. Transmit antenna 46 is substantially tuned to a plurality of independent frequency bands individually having a bandwidth of approximately twenty percent of the highest center frequency. Transmit antenna 46 is tuned to plural exclusive non-overlapping frequency bands in the described arrangement.

For example, the depicted transmit antenna 46 is substantially tuned to 915 MHz and 2.45 GHz. Horizontal portions 82, 86 of transmit antenna 46 are tuned to substantially communicate at a first

frequency (e.g., 2.45 GHz communications). Vertical portions 80, 84 of transmit antenna 46 in combination with horizontal portions 82, 86 are tuned to provide communications at a second frequency (e.g., 915 MHz) with horizontal portions 82, 86. Transmit antenna 46 is configured to electromagnetically communicate with a return loss of less than or equal to approximately -9 dB at the plurality of frequencies. Provision of impedance reduction strip 72 operates to improve tuning of transmit antenna 46 to the plural independent frequency bands.

Interrogator 26 (shown in Fig. 1) is configured to communicate at one or more of a plurality of frequencies. The frequency of communication intermediate interrogator 26 and remote communication device 12 is generally controlled by interrogator 26. For example, in some applications, a 915 MHz frequency may be desirable for longer range communications while in other applications a 2.45 GHz frequency may provide advantageous benefits (e.g., severe interference may be experienced in another one of the frequency bands). Interrogator 26 outputs forward signals 27 at the desired frequency or frequencies.

Thereafter, interrogator 26 outputs a continuous wave signal at one or more of the frequencies. Remote communication device 12 selectively modulates a received continuous wave signal during backscatter communications. Accordingly, the modulated backscatter return signal is provided at the original frequency of the continuous wave signal outputted by interrogator 26. Thus, in the described embodiment, the frequency of communication of remote communication

device 12 is determined responsive to a frequency of communication of interrogator 26. Other communication methods may be utilized.

Referring to Figs. 5-7, exemplary dimensions of receive antenna 44 and transmit antenna 46 formed upon surface 52 are illustrated. Referring specifically to Fig. 5, dipole half 47 of transmit antenna 46 is shown. Vertical portion 80 of dipole half 47 has a thickness a of 2.3 mm. Vertical portion 80 additionally includes a length b of 55 mm. Horizontal portion 82 has a length c of 22.3 mm. Horizontal portion 82 additionally includes a width d of 3 mm.

Referring to Fig. 6, details of dipole half 48 are shown. Dipole half 48 includes a vertical portion 84 and a horizontal portion 86 adjacent impedance reduction strip 72. Vertical portion 84 has an equivalent width and length to that of vertical portion 80 of antenna half 47. Further, horizontal portion 86 has a length equivalent to that of horizontal portion 82 of antenna half 47. A dimension g including the width of horizontal portion 86 and the width of impedance reduction strip 72 is 7.73 mm. Another dimension h including a reduced width of impedance reduction strip 72 and horizontal portion 86 is 5 mm. Further, a dimension i corresponding to one length of impedance reduction strip 72 is 17 mm. The depicted dimensions correspond to one configuration of transmit antenna 46 of remote communication device 12. Other configurations are possible.

Referring to Fig. 7, exemplary dimensions of receive antenna 44 are shown. Receive antenna 44 includes horizontal portions 88-90. In

addition, receive antenna 44 includes vertical portions 92, 93. Horizontal portions 88, 89 individually have a length corresponding to a dimension m of 14.7 mm. Individual antenna portions 88-90, 92, 93 individually have a width corresponding to dimension n of 1.35 mm. Vertical portions 92, 93 individually have a length o having a dimension of 33.8 mm. Horizontal portion 90 also has a length of dimension o of 33.8 mm. Impedance reduction strip 70 and horizontal portion 89 have a combined width p of 5.73 mm.

Referring to Fig. 8, a surface 55 of substrate 50 opposite surface 52 described above is shown. Surface 55 of substrate 50 includes conductive traces 57 formed as shown in the described embodiment. Conductive traces 57 can comprise etched copper cladding in an FR4 board configuration.

The depicted conductive trace 57 includes a ground plane 96 and a transmission line 97 comprising plural conductors 98, 99. Ground plane 96 is coupled with negative connection 56 using via connection 62. Further, ground plane 96 is also coupled with via connections 66, 74.

Transmission line 97 comprises a quarter-wavelength transmission line in the described embodiment. Transmission line 97 operates to couple backscatter pins 5, 6 of integrated circuit 19 shown in Fig. 4 with respective dipole halves 48, 47 of transmit antenna 46. Transmission line 97 operates to provide an inverting function in accordance with the described embodiment. For example, if integrated circuit 19 short circuits pins coupled with via connections 68, 69, an

open circuit is seen at via connections 71, 73 coupled with antenna halves 47, 48. Conversely, if an open circuit is provided intermediate via connections 68, 69, a short circuit is seen at via connections 71, 73 for 2.45 GHz communications.

Various dimensions of conductive trace 57 are provided below in accordance with an exemplary configuration. Other configurations are possible. In the described embodiment, ground plane 96 includes a width of dimension s of 8.44 mm. Further, ground plane 96 has a length t of 34 mm. Conductors 98, 99 individually have a length corresponding to dimension u of 10.5 mm. Further, individual conductors 98, 99 have a width of 1 mm.

Provision of a remote communication device 12 as described herein provides improved communications at plural independent frequency bands. For example, such a remote communication device 12 has been observed to have a forward range of approximately 170 feet and a return range of approximately 300 feet at 915 MHz. Further, the remote communication device has been observed to have a forward range of 28 feet and a return range of 90 feet at 2.45 GHz.

In compliance with the statute, the invention has been described in language more or less specific as to structural and methodical features. It is to be understood, however, that the invention is not limited to the specific features shown and described, since the means herein disclosed comprise preferred forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or

modifications within the proper scope of the appended claims appropriately interpreted in accordance with the doctrine of equivalents.